REPORT OF GEOTECHNICAL CONSULTATION
PINNACLES NATIONAL MONUMENT, CALIFORNIA
FOR
U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

DAMES & MOORE

ENVIRONMENTAL AND
APPLIED EARTH SCIENCES

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DAMES & MOORE
DENVER, COLORADO

October 6, 1976

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October 6, 1976

U.S. Department of the Interior
National Park Service
Western Regional Office
450 Golden Gate Avenue
San Francisco, California 94102

Attention: Mr. Gerard S. Witucki

Gentlemen:

This letter transmits eight (8) copies of our "Report of Geotechnical Consultation, Pinnacles National Monument, California."

It has been a pleasure for us to work on this project. Please do not hesitate to call us if you have any further questions.

Very truly yours,

DAMES & MOORE

Michal Bukovansky

Michal Bukovansky
Partner

MB:jad
Attachment

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REPORT OF GEOTECHNICAL CONSULTATION

PINNACLES NATIONAL MONUMENT, CALIFORNIA

FOR

U.S. DEPARTMENT OF INTERIOR

NATIONAL PARK SERVICE

1. INTRODUCTION

In late August 1976, the National Monument staff members discovered a large rock failure in the narrow canyon of the Bear Gulch Creek close below the dam of the Bear Gulch Reservoir. For safety reasons, the area of the rock failure was closed to the Monument visitors.

Mr. G. S. Witucki, geologist of the Western Regional Park Service office visited the site on September 1, 1976. He recommended a more detailed inspection and evaluation of recent stability conditions of the area since a large remainder of the partially failed block still poised above the canyon comprised the potential hazard to the visitors.

On September 23, 1976, the site was inspected once more in detail by Messrs. G. S. Witucki and M. Bukovansky from Dames & Moore. The purpose of this visit was to evaluate the stability conditions of the remaining block portion and to recommend remedial measures, if deemed necessary.

Extensive discussions on the stability problem and remedial measures were held with the National Monument Superintendent, Mr. Rothwell P. Broyles and Mr. J. Worsham, Chief of Maintenance.

This report presents our evaluation of the block stability, discussion of various types of remedial measures and our recommendations. Valuable comments and suggestions of the Monument staff members and Western Region office professionals have been taken into account while preparing this report.

2. SITE CONDITIONS

2.1 GEOLOGIC FEATURES

The Bear Gulch Creek area where the failure occurred is formed entirely by Tertiary volcanic rocks that have a typical character of volcanic breccias (angular fragments of rhyolitic rocks cemented by softer tuffs). Bear Gulch Creek eroded a narrow, deep canyon with vertical or subvertical walls at this site. Volcanic rocks of the area exhibit a distinct layering and vertical jointing and they have a low resistance against weathering and erosion. As a result of the erosion, weathering and the rock structure, rock falls have been frequent in geological past. Picturesque cliffs, spires and pinnacles have been formed and countless failed blocks have filled the valleys below them. They form so called caves in the lower portion of the gulch.

It can be assumed that most rock failures are not recent and that they occurred during the Pleistocene time. Recent failures are very rare.

The August failure thus comprises an unusual event. Careful inspection of the base of the failed block and of the remaining portion reveals that the block is not an integral part of the underlying bedrock. The block failed in the past, probably at the same time as the blocks filling the gulch. The block, however, did not fall all the way down to the valley bottom as most of the other blocks. Instead, it remained poised very close to the crest of the canyon, in a small, V-shaped gully. As far as we can determine, the block rests partly on bedrock and partly on coarse-grained soils filling the gully.

The finding that the block is not an integral part of the underlying rock is important from the stability point of view, as will be discussed later.

2.2 STABILITY CONDITIONS

The large rock block, resting close to the canyon crest, has been split by a vertical fracture, parallel with the crest into two portions. The fracture apparently developed along a vertical joint. Roots and water pressure combined with unusually high day-night temperatures changes have contributed to the fracture propagation.

For reasons, which cannot be accurately explained, the block portion closer to the crest failed last month. We suspect that a heavy rain recorded prior to the failure was the main reason for the failure. Water could develop considerable pressures in the vertical fracture and at the same time, it could reduce significantly the friction between the block and its base.

We suspect that the failed block portion was not completely separated from the remaining portion of the block. During the failure and final splitting of both portions, a considerable horizontal force could pull the remaining portion down. This could explain an evident horizontal displacement of the remaining block portion, which has reached some six inches.

The inspection of the remaining block shows that the block rests in the shallow gully close to the canyon crest. Due to the irregularities in the shape of the block base and of the gully bottom, the block is not in a full contact with the surface. It is rather wedged in on three planes. The contract areas on these planes are small and the rest of the block is unsupported. There is a fairly large cave filled with rock debris and soils below the block side closer to the crest.

Stability of such a block depends entirely on the inclination of the supporting planes and on the friction angle of these planes. Generally, when the inclination of the supporting planes is lower

than the friction angle, the block is stable. If the inclination angle is higher than the friction angle, the block slides down and fails.

This simple rule assumes dry conditions and no other forces acting on the block (earthquake forces).

Our inspection showed that the inclination of the supporting planes is on the order of 40 to 45 degrees. We can reasonably assume that the friction angle of the supporting planes is on the same order of 40 to 45 degrees (this is an upper bound of friction angles for any dividing plane in rock).

It can bee seen from this evaluation that the block is only marginally stable in dry conditions. A heavy rain can decrease the friction angle and the block would fail. An earthquake can cause the block failure as well.

In summary, the stability of the remaining block is only marginal at present and its failure could be expected after heavy rains or during an earthquake. Remedial measures are recommended prior to re-opening of the area to the visitors.

3. REMEDIAL MEASURES

3.1 GENERAL

There are several ways how to eliminate the existing failure hazard. The choice of an appropriate method depends on a number

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of circumstances. Remedial measures are divided into two groups: stabilization methods and removal. Stabilization can be chosen if the block should be conserved at its present location for environmental reasons; the block could be removed and the hazard eliminated as another alternative.

3.2 STABILIZATION

The cave below the block provides an opportunity to stabilize the block by "underpinning". A small supporting wall could be built below the block as shown on Plate 1. Walls of this type were frequently used to stabilize loose blocks above highways and railroads some 50 to 70 years ago when no other means of support were available.

Their disadvantage is that they are difficult to build and they require a time consuming preparation of the foundation. A horizontal berm would have to be excavated below the block to obtain a reliable foundation for the wall. The wall itself could be built from concrete or from local stone as a masonry wall. The space behind the wall would have to be filled by cement grout (without pressure) to achieve a full contact between the block and its base.

Rock bolting comprises a more advanced and frequently used method of stabilization. A scheme of rock bolting is shown on Plate 1. Several holes 1 to 1 1/2 inch diameter would be drilled through the block and some 4 feet into the bedrock below the block. Rock bolts (rebars) 3/4 to 1 inch diameter would be installed in the holes and grouted with cement or polyester resin grout. A steel

plate and a nut on the outer end would be used to tighten the block into the ground.

According to our preliminary evaluation, some 3 to 4 bolts should be used to stabilize the block. For a higher safety, bolting could be combined with a supporting wall as discussed earlier. The number of bolts could be decreased to 2 in such a case.

Both stabilization methods would require tools such as percussion drills and jackhammers. Since there is no possibility to transport a compressor to the site, gasoline powered tools would have to be used.

With regard to the marginal stability of the block, temporary stabilization would be required during the construction to ensure the safety of the personnel. The block could be temporarily stabilized by means of cables anchored safely to the block and to several anchors installed in the bedrock above the block. In addition to this temporary stabilization, daily inspections would be required to detect any potential deformations of the block.

3.3 REMOVAL

The removal of the block probably comprises the fastest and least expensive means to eliminate the existing safety hazard. The block could be removed by blasting, manual splitting or simply by pushing or pulling it over the crest of the canyon.

The block could be blasted as one piece down over the crest or disintegrated using small charges in holes drilled into the block. We do not recommend any of these methods; blasting the block down would require a fairly large charge, which could cause damage to the surrounding area (flying rock fragments, vibrations). Blasting with small charges would require careful temporary stabilization of the block with the help of cables and anchors; even under these conditions, the risk of the block failure would be fairly high.

Manual splitting of the block was suggested by the Monument staff. This method requires drilling of a large number of holes into the block. The holes are arranged in lines so that a slab of required dimensions can be broken off the block. Mechanical wedges are inserted into the holes to develop necessary forces to break the rock.

This method is known from quarries supplying structural and monumental stone. It is time-consuming and requires specialized tools. It would be, however, very desirable, if there is a need for rock for other purposes such as the construction of trails.

Temporary stabilization of the block would be required for this method to ensure the safety of working personnel.

An obviously simplest method to remove the block is to push or pull it down over the crest of the canyon. We have examined carefully the topography of the canyon walls (an approximate section

across the canyon is shown on Plate 2) and the path of the August 1976 failure. It can be seen that the block portion fell mostly on the opposite side of the canyon and partly on the old block, which is wedged in close to the canyon bottom. No damage to the existing visitors trail, which is protected at this location by a distinct overhang, could be observed.

It can be reasonably assumed that if the remaining block is pushed or pulled down, it will follow a similar fall path and it will not damage the existing trail. The risk of damage, however, cannot be ruled out, since a portion of the falling block could split off and hit the trail. This risk is, in our opinion, very small. The trail could also be protected against any damage by a rock fill, sand bags or by an appropriate lumber protection.

The magnitude of horizontal forces required to bring the block over the crest cannot exceed some 50 tons. This is a conservative estimate and we believe that a force of some 10 to 20 tons would be sufficient.

Two hydraulic jacks (with 10 to 20 tons capacity each) would be required to push the block down. The jacks would be installed between the block and the bedrock above (close to the upper trail) on both side of the block. It is possible that the position of the jacks would have to be changed several times to achieve sufficient displacement of the block to force it to fall. Pushing the block down is probably the safest method of removal.

Pulling the block from the opposite side of the canyon would be another method of removal. Cables could be attached to the block by means of short anchors or simply by winding the cable around the block. The cable could be anchored on the other side of the canyon. One or two anchors could be installed in short holes drilled into the rock or a cable could be wrapped around a large rock block resting on this canyon side. A ratchet or a winch could be used to develop the necessary horizontal force. A safety release mechanism would have to be installed at the block or the other side of the valley if the cable length is not sufficient for the total fall path.

The gully where the block is located would require careful cleaning and scaling after the block removal since the rock debris falling from above could endanger the visitors on the lower trail.

4. RECOMMENDATIONS

The rock block poised above the Bear Gulch Creek was found to be only marginally stable and remedial measures are recommended if the area should be re-opened and made accessible to the visitors.

The block can be either stabilized or removed. The decision on the appropriate method of treatment depends on a number of circumstances that are outside the scope of our study.

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From a purely engineering point of view, the removal of the block is preferable to stabilization; it is safer, faster and more economical than any other method; pushing or pulling the block from the opposite canyon side appear to be the simple ways of developing the necessary horizontal force.

Mechanical breakage of the block without using explosives is a viable alternative if rock is required for other purposes. Evidently, this method is more expensive than a simple removal.

Respectfully submitted,

DAMES & MOORE

Michal Bukovansky

Michal Bukovansky
Partner

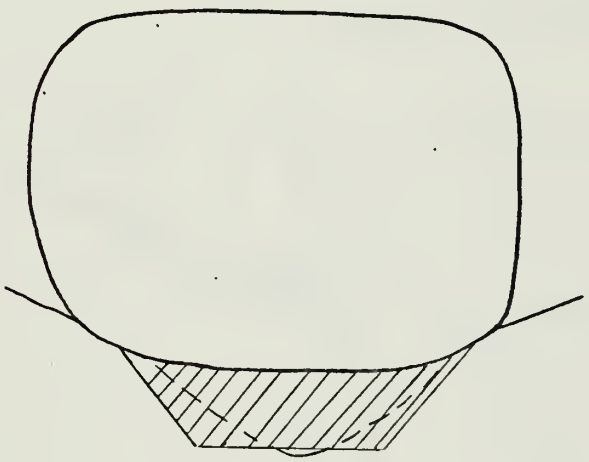
MB:jad

STABILIZATION

NOT TO SCALE

1. WALL BELOW THE BLOCK

FRONT VIEW



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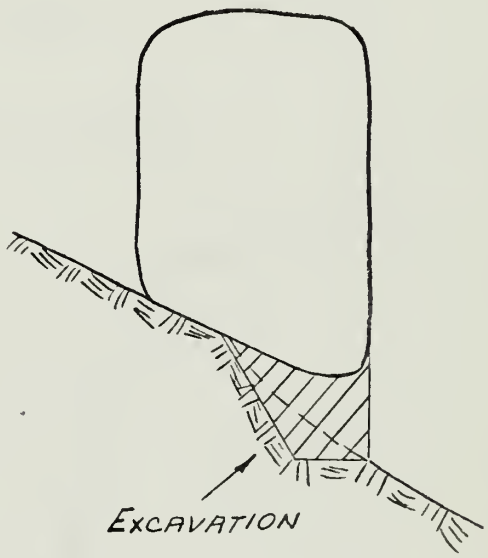
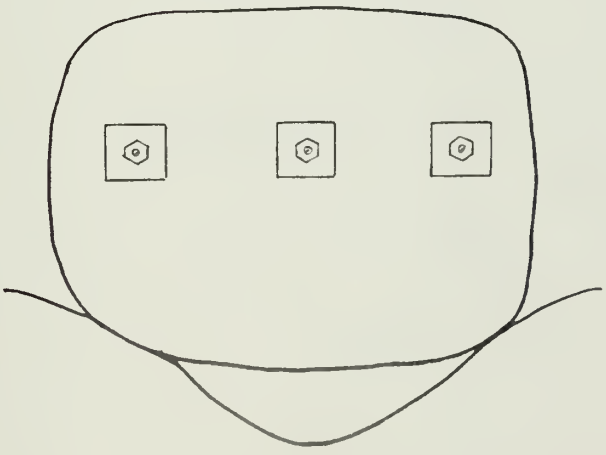


2. BOLTING OF THE BLOCK

FRONT VIEW



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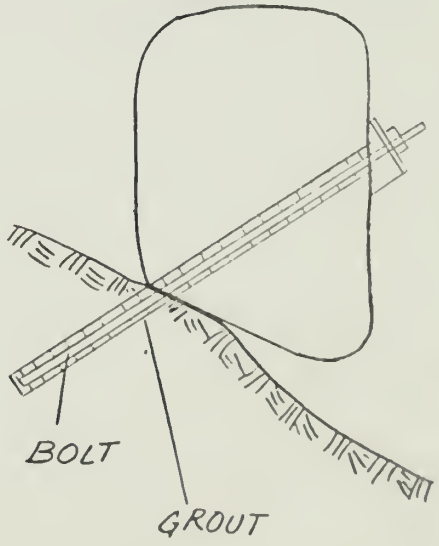

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PLATE 1

APPROXIMATE SECTION ACROSS THE VALLEY

NOT TO SCALE

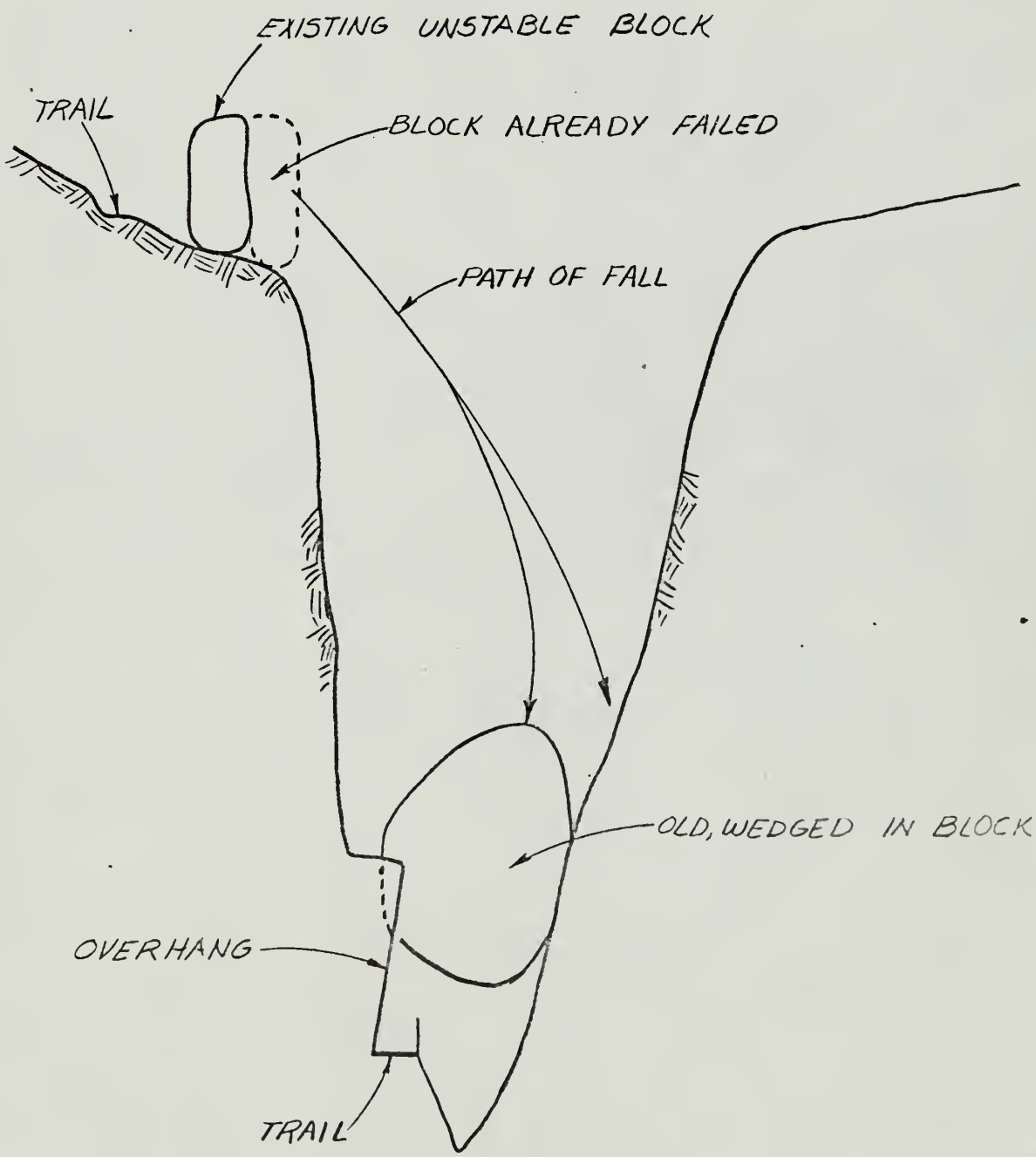

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PLATE 2